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MEASUREMENT OF THE EFFECTIVE GAIN
OF A
RESONANT SLOT

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INTRODUCTION

The material for this report was taken from the Master of Science thesis of Peter Fagan. It presents mainly the results of the research and indicates the agreement that can be expected between the theoretical predictions and several sets of carefully-made experimental measurements. Details of the analysis and the experimental procedure can be furnished upon request.

Three gain measurements are described in the following sections. First, the gains of two similar horns were measured. One of these horns was then used to measure the gains of the two remaining slot antennas: a thin half-wave resonant slot in a ground plane, and a waveguide opening into a ground plane. The thin resonant slot was constructed by cutting a longitudinal slot in the broad face of a section of waveguide and attaching a metal plate to extend the broad side of the waveguide into a large ground plane. The measurements were performed at a wavelength of 3.20 centimeters, or a frequency of 9.37 kilomegacycles.

It was thought that these gain measurements might provide a knowledge of the difficulties encountered in measuring the gains of slots in ground planes. These slot antennas were convenient to use because their measured gains could be compared with their calculated gains. The waveguide opening into a ground plane was also investigated as a possible gain standard.

MEASUREMENT OF THE GAINS OF TWO SIMILAR HORNS

In order to obtain an antenna of known gain for use in the slot gain measurements, the gains of two similar pyramidal horns were measured. The horns were constructed as nearly alike as possible. The dimensions of the horn are given in Figure 1.

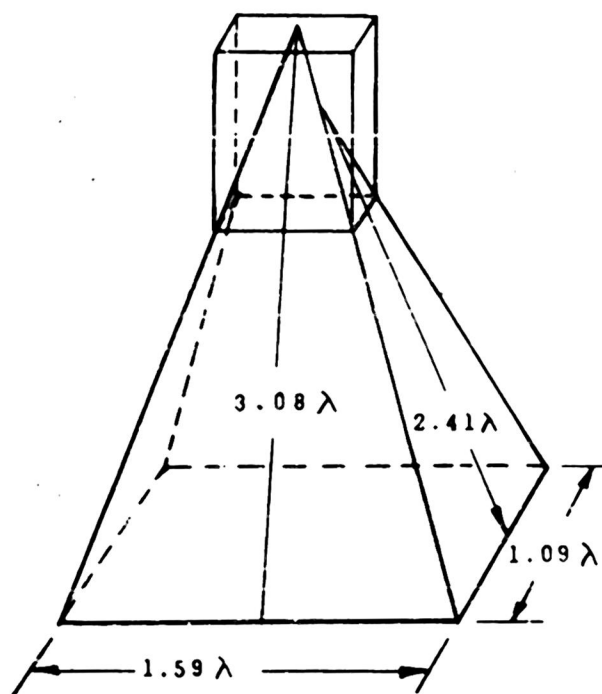


FIG. 1 HORN DIMENSIONS

The two horns were directed into free space and matched (VSWR < 1.02) to the waveguide by means of the three-screw tuners.

The barretter on the receiving antenna was matched (VSWR < 1.02) to the waveguide by means of the third three-screw tuner.

Gain measurements were carried out at several separation distances. At each separation distance the horns were aligned for maximum received power. The receiving antenna could be adjusted in azimuth, horizontal position, height, and, with considerable effort, angle of elevation.

Using the equation

$$\frac{P_r}{P_t} = \frac{G_1 G_2 \lambda^2}{(4\pi R)^2} \quad (1)$$

these measurements determined the product of the gains of the horns as a function of separation distance. Additional experiments showed that the gains of the horns were essentially equal, so that these measurements actually determined the gain of either horn. The results are shown as the points on the "Measured gain" curve of Figure 2. The drop in the measured gain at short separation distances is of the order of magnitude to be caused by near-field effects. A criterion for the minimum separation distance at which the far-zone gain of an antenna can be measured is often given as $2D^2/\lambda$ to $4D^2/\lambda$, where D is the greatest linear dimension of the aperture of the antenna. These distances are $R/\lambda = 7.4$ and $R/\lambda = 14.9$ in this experiment, and the gain is down 0.1 db, or 2.3 percent, and 0.02 db, or 0.5 percent, respectively, at these two points. The far-zone gain of either horn was taken as 12.54 db, or 17.95.

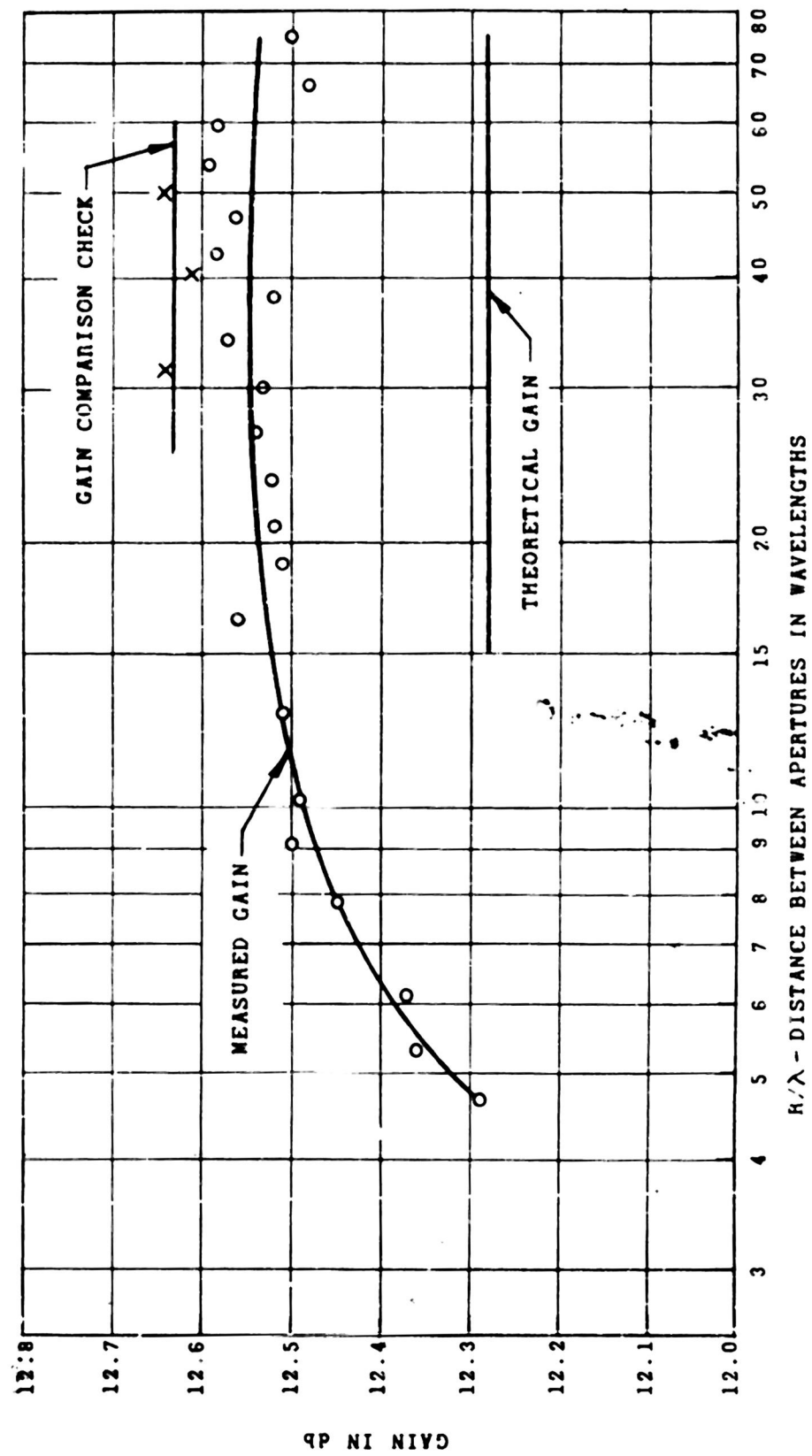


FIG. 2 GAIN OF THE PYRAMIDAL HORN SHOWN IN FIGURE 1

To show that the two horns had essentially equal gains, an additional experiment was performed using a third horn. The third horn was set up as the transmitter, and the ratio of the powers received by the two horns when they were alternately used as receivers was measured. The ratio of the received powers was equal to the ratio of the gains of the two horns. This experiment was performed at three separation distances, 31λ , 39λ , and 47λ . The ratios of the received powers, or the ratios of the gains, at these distances were 1.005, 1.01, and 1.005, respectively, one horn having a consistently higher gain. These ratios were approximate since the meter could not be read accurately to 0.5 percent.

It was possible to check the measured gains of the two similar horns using the third horn. The gain of this third horn was measured by Henschke¹ and found to be 46.2 ± 5 percent, or $16.65 \text{ db} \pm .2 \text{ db}$. One of the two similar horns was used as a transmitter, and the ratio of the powers received by its mate and the third horn was measured at three separation distances. The values of gain, calculated from these measurements, are shown as crosses in Figure 2, and the curve through them is called the "Gain comparison check".

Finally, the theoretical gains of the two horns were calculated from their physical dimensions by means of Schelkunoff's²

¹R.A. Henschke, "A Primary Gain Standard for Microwave Antennas", University of California Antenna Laboratory Report No. 159, December 23, 1949, Chapter 6.

²S.A. Schelkunoff, Electromagnetic Waves, Van Nostrand, New York, 1943, Chapter 9.

formulas. The physical dimensions of the two horns were essentially equal so that the theoretical gains were equal. The theoretical gain of either horn is shown in Figure 2. It is within about 0.26 db of the measured gain.

Errors due to misalignment of the antennas did not seem important during the experiment. After a distance of about 15 or 20 wavelengths was reached, slight movements of the receiving antenna in azimuth or elevation did not cause a perceptible change in the received power.

The possible errors named above were considered to be negligible for those measurements between 10 and 30 wavelengths, so that the accuracy of the gain measurements was dependent only upon the accuracy of the calibrated attenuator. Since the accuracy of the calibrated attenuator was $\pm .2$ db, or about 5 percent, and since the gain varied only as the square root of the power ratio, the accuracy of the measured gain was about 0.1 db, or 2.5 percent. It may be observed from Figure 2 that the spread of the points about the measured gain curve is only about $\pm .05$ db, and the gain comparison check is within about .1 db.

MEASUREMENT OF THE GAIN OF A RESONANT SLOT

The first slot antenna to be investigated was a thin half-wave resonant slot in a metallic sheet. The electromagnetic fields produced by a thin half-wave resonant slot in a perfectly conducting metallic sheet of infinite extent have been calculated by Begovich¹. The space dependence of the fields was shown by Begovich to be the same as that of a half-wave resonant wire antenna, but with the electric and magnetic fields interchanged. The theoretical power patterns of the two antennas are identical in either case.²

It was desired to cut a thin longitudinal half-wave resonant slot in the broad side of a section of waveguide and to provide an extension of the broad side of the waveguide into a large ground plane surrounding the slot. To accomplish this, 0.020 inches were milled off one of the flat broad faces of a bent section of 1.0" x 0.5" x 0.050" waveguide, and a flat circular brass plate 1 1/4 inches in diameter and 0.020 inches thick was soldered to the milled face. The slot was then cut through the brass plate and the remainder of the guide wall.

The 1 1/4-inch slot assembly was mounted in a larger ground plane. The larger ground plane consisted of a rectangular sheet of 1/16 inch aluminum, 60 inches wide and 81 inches long, attached to a plywood base. Figure 3 is a section drawing of the slot

¹N.A. Begovich, "Slot Radiators", Proceedings of the Institute of Radio Engineers, vol. 38, no. 7, pp. 803-806, July 1950.

²The power patterns and the gain of a thin half-wave resonant wire antenna may be found in S. Silver, Microwave Antenna Theory and Design, McGraw-Hill, 1949, pgs. 98-99, and J.A. Stratton, Electromagnetic Theory, McGraw-Hill, 1941 Chapter VIII.

assembly mounted in the aluminum ground plane.

The position, resonant length, and width of the slot shown in Figure 4 were taken from data given by Watson¹. The type of circuit element that this radiating slot presents to the transmission line representation of the propagating TE_{10} mode in the waveguide is a pure shunt conductance, G , when resonant, and a shunt admittance, $G + jB$, when not resonant. The shunt conductance or admittance may be considered as lumped at the position of the center of the slot in the transmission line representation. To terminate the waveguide a short-circuiting brass plate was soldered across the waveguide at a distance of $\lambda_g/4$ from the center of the slot, where λ_g is the guide wavelength. The transmission line representation of the shorted section of waveguide beyond the center of the slot is an open circuit, so that the equivalent transmission line is terminated by the shunt conductance or admittance representing the slot. The shorting plate was actually placed $\lambda_g/4 + \lambda_g/2$ from the center of the slot, so that the higher mode structure about the slot was not disturbed.

Values of the normalized shunt admittance, $g + jb$, of the slot in the transmission line representation were measured over the frequency range, 8.95 kmc to 9.60 kmc, and are shown in Figure 5. The normalized shunt admittance is given by $g + jb = G/Y_0 + jB/Y_0$, where Y_0 is the characteristic admittance

¹W.H. Watson, "Resonant Slots", Jour. of the Institution of Electrical Engineers, vol. 93, Part IIIA, no. 4, pp. 747-777, March-May, 1946.

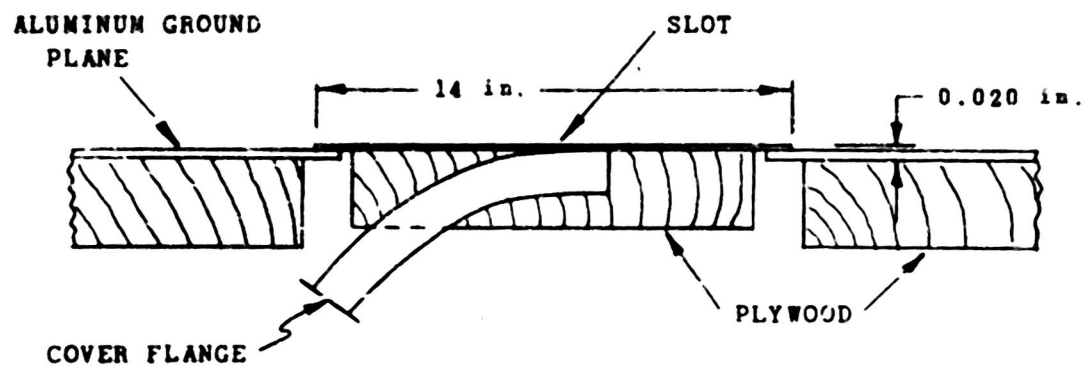


FIG 3 SECTION DRAWING OF THIN RESONANT SLOT ASSEMBLY MOUNTED IN ALUMINUM GROUND PLANE.

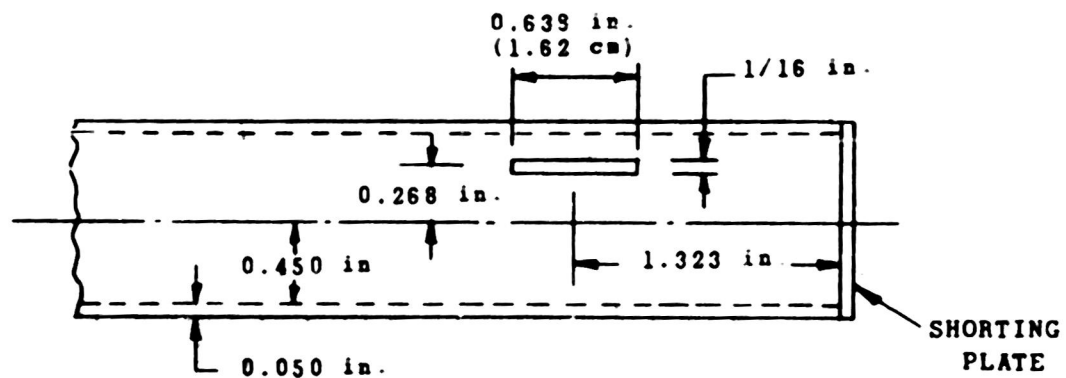


FIG. 4 DIMENSIONS, POSITION, AND ORIENTATION OF SLOT IN BROAD FACE OF WAVEGUIDE..

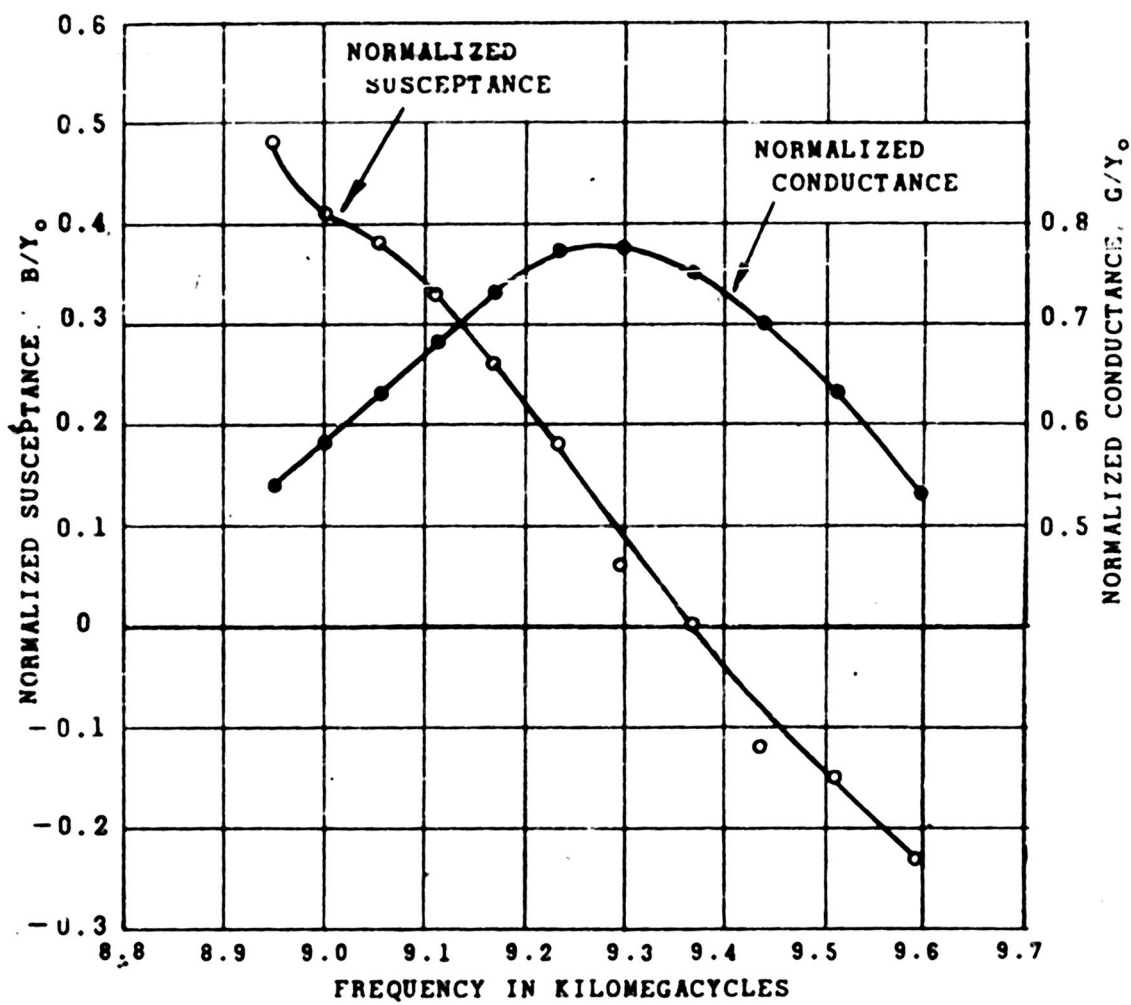
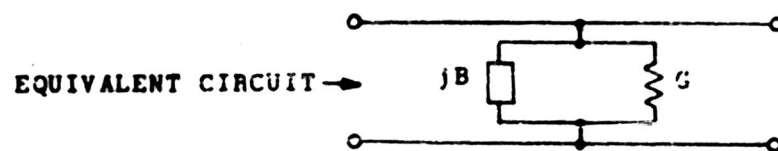


FIG. 5 ADMITTANCE OF THIN LONGITUDINAL SLOT SHOWN IN FIG. 4

of the equivalent transmission line.¹

The standing-wave measurements were made with a PRD Type 203-A waveguide slotted section and a PRD Type 250 probe. The electrical distance between the center of the slot and a reference point on the slotted section scale was measured by clamping a brass plate over the outside surface of the slot assembly and finding the position of a minimum on the slotted section scale.

The normalized admittance at 9.365 kilomegacycles was measured with two different standing-wave machines. In both measurements the positions of the minimums, with and without the brass cover plate over the slot, were identical, so that both values of the normalized susceptance were zero at this frequency. Therefore, the resonant length of the slot agreed with that given by Watson. However, Watson gives a value of 0.80 for the normalized conductance at resonance, and the measured value of the normalized conductance at 9.365 kilomegacycles on Figure 5 is 0.75. This small difference may be due to the fact that Watson's data were taken from slots in waveguides which did not have ground plane extensions of the broad sides of the guides.

Figure 6 is a diagram of the arrangement of the components used to measure the gain of the thin resonant slot. The detecting horn indicated in Figure 6 is one of the two horns whose calibration was described in the last section.

¹S. Silver, Microwave Antenna Theory and Design, McGraw-Hill, 1949, Chapter 2.

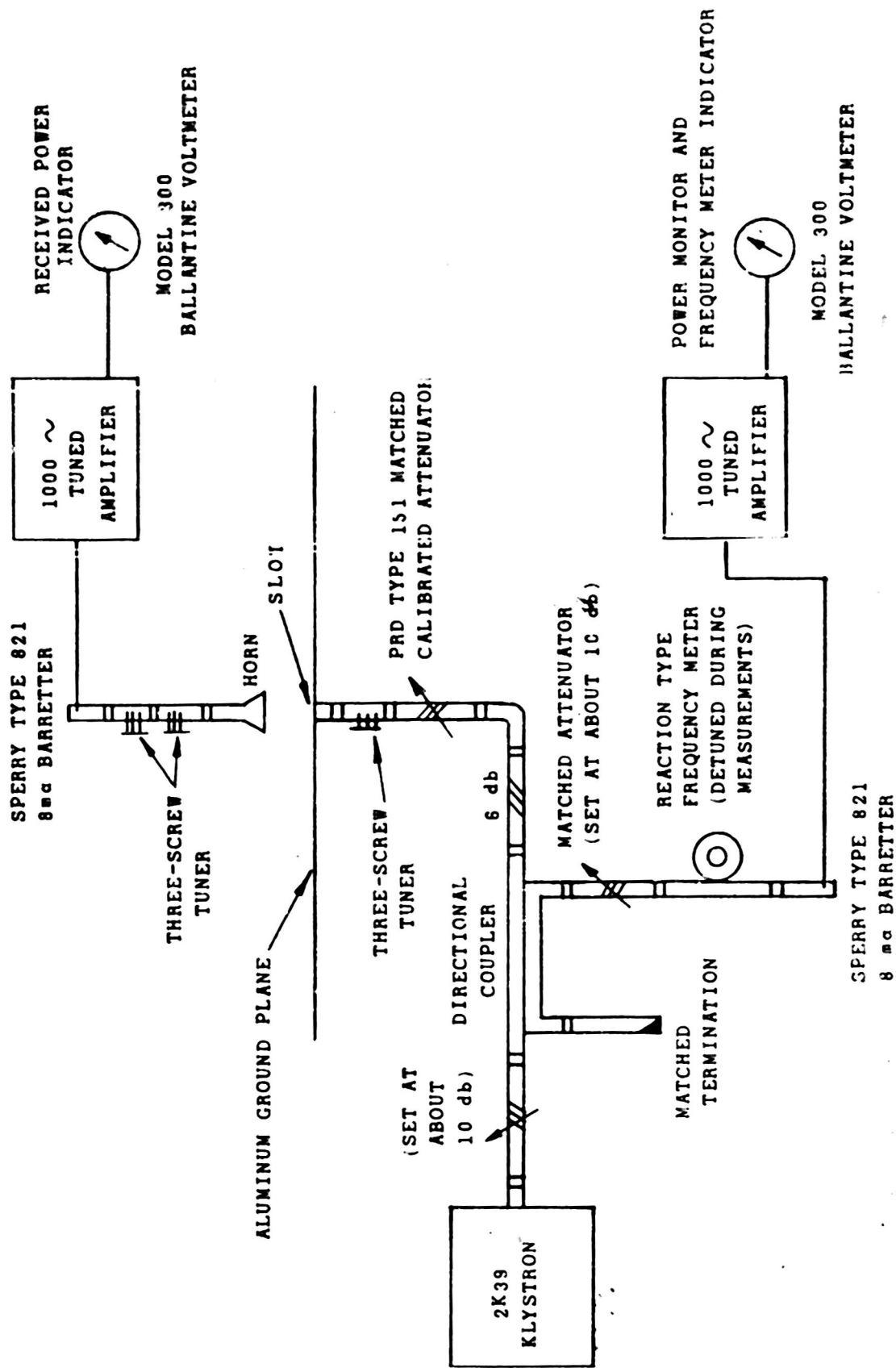


FIG 6 DIAGRAM OF SLOT GAIN MEASUREMENTS

Preliminary gain measurements showed that multiple reflections between the receiving horn and the ground plane caused large periodic variations in the received power as the distance between the horn and the ground plane was varied. Figure 7 shows one cycle of the periodic variation in received power as the separation distance was varied about 22.0 centimeters. The curve in Figure 7 was obtained by recording the relative power received at millimeter intervals. The period of the variation in received power is 1.60 centimeters, or $\lambda/2$. At separation distance of 22 centimeters or greater, the average received power is nearly inversely proportional to the square of the distance of separation.

An averaging procedure may be applied to compensate for the effects of multiple scattering.¹ An arithmetic (or geometric) average of the gains at the positions of adjacent maximum and minimum received powers is taken. Using Figure 7, the difference between the gains, calculated first by averaging over the long half-period and then over the short half-period, was less than 0.1 db.

To determine the gain of the slot it was necessary to measure five physical quantities: two distances between the ground plane and the horn at which adjacent maximum and minimum

¹S. Silver, Microwave Antenna Theory and Design, McGraw-Hill, 1949, pages 587-592.

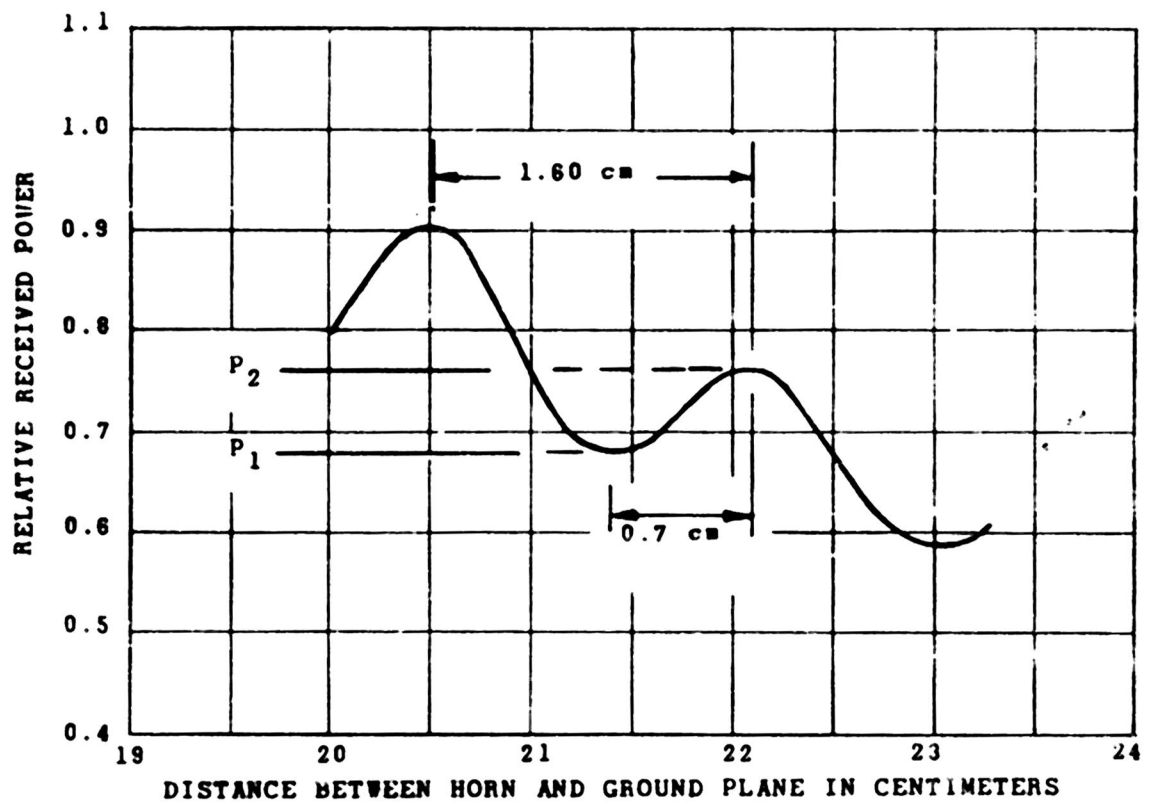


FIG. 7 COMPLETE CYCLE OF THE PERIODIC VARIATION IN RECEIVED POWER OBTAINED WITH A THIN RESONANT SLOT IN THE GROUND PLANE

received powers were observed, the ratios of the transmitted and received powers at these distances, and the operating wavelength. From these quantities and the gain of the horn, the gain of the slot could be calculated by means of equation (1) and the averaging procedure given above. The resulting value of gain was assigned a separation distance halfway between those distances at which the maximum and minimum were found.

A few sets of measurements of the gain of the thin half-wave slot were made and results are shown in Figures 8, 9, and 10. The particular orientation for each value of gain given in Figures 8, 9, and 10 is shown in the top right hand corners of the graphs. Figure 8 shows two complete sets of gain measurements, one set for each orientation of the slot in the ground plane. Figure 9 shows two complete sets of gain measurements taken with the same orientation of the slot. Figure 9, then, shows the accuracy with which each gain measurement could be reproduced. A comparison of Figure 8 with Figure 9 shows that the differences in the values of gain measured with the two slot orientations were about the same as the differences between repeated measurements of the gain at any distance. The set of gain measurements denoted by open circles in Figure 8 is the same set denoted by open circles in Figure 9.

A comparison of Figures 8 and 9 with Figure 2 shows that the scatter of the values of the measured gain of the thin resonant slot was considerably greater than that of the horn. It was thought that reflections from the wooden beam which held the receiving antenna might have caused the increased scatter



ORIENTATIONS OF SLOT IN
GROUND PLANE

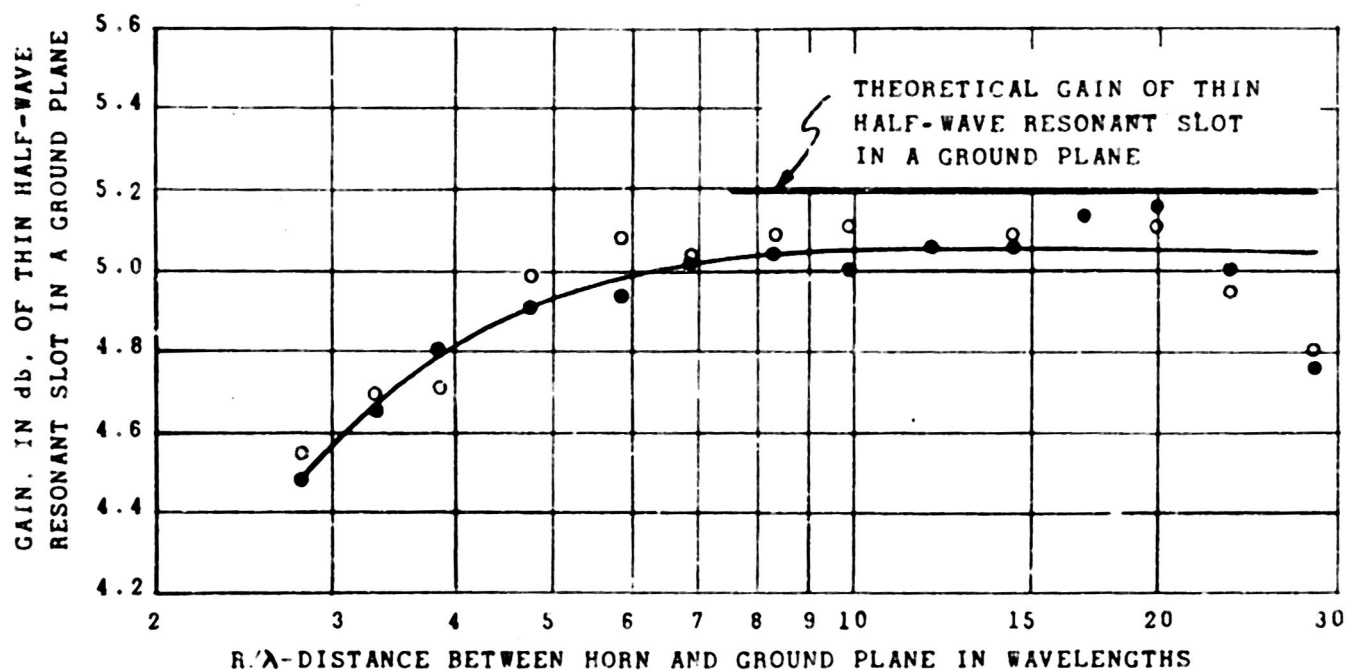
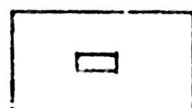


FIG. 8 TWO SETS OF GAIN MEASUREMENTS TAKEN WITH DIFFERENT
ORIENTATIONS OF THE THIN RESONANT SLOT IN THE
GROUND PLANE



ORIENTATION OF SLOT
IN GROUND PLANE

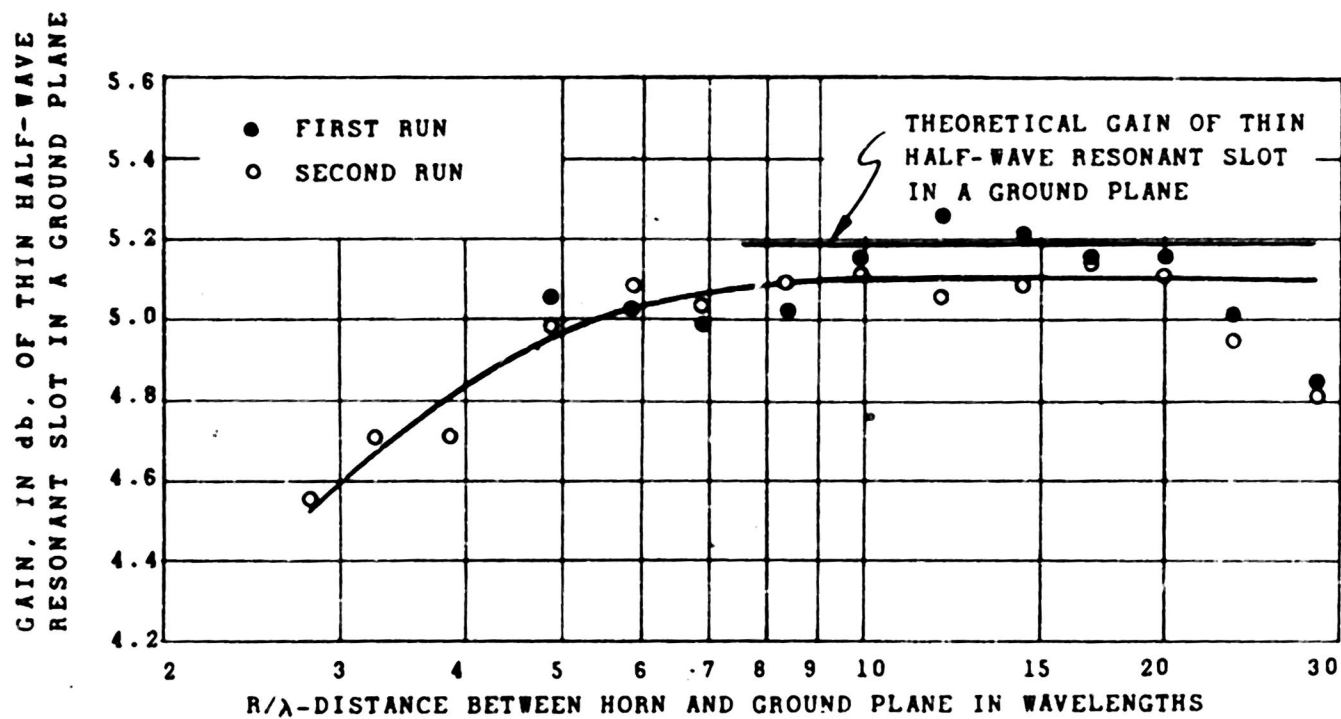
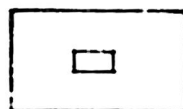


FIG. 9 TWO SETS OF GAIN MEASUREMENTS TAKEN WITH THE
SAME ORIENTATION OF THE THIN RESONANT SLOT
IN THE GROUND PLANE.



ORIENTATION OF SLOT
IN GROUND PLANE

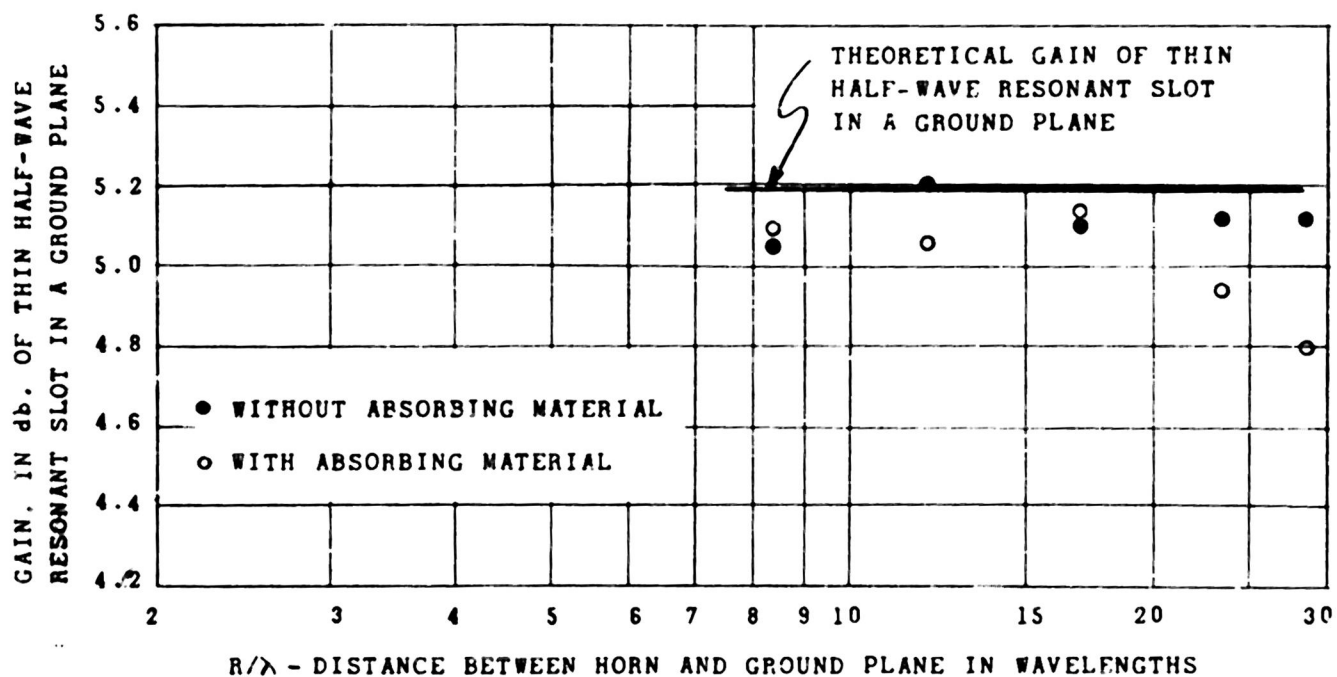


FIG. 10 TWO SETS OF GAIN MEASUREMENTS TAKEN WITH AND WITHOUT
ABSORBING MATERIAL TIED TO THE BEAM OF THE GROUND
PLANE. (THIN RESONANT SLOT IN A GROUND PLANE)

of the points. Accordingly, blocks of absorbing material were mounted on the beam. These blocks of absorbing material were mounted on the beam when the values of gain shown in Figures 8 and 9 were measured. To determine the effectiveness of the absorbing blocks, a few values of gain were measured with and without the blocks. These values of gain are shown in Figure 10. Except for the last two pairs of points, the differences between the two sets of measurements shown in Figure 10 are about the same as the differences between repeated measurements of the gain at any distance. The last two pairs of points seem to indicate that the measured values of gain without the absorbing material are in better agreement with the theoretical gain curve than those with the absorbing material.

In an attempt to determine why the values of gain obtained for the thin resonant slot were more erratic than those obtained for the horns, patterns were taken for the thin resonant slot. Six of these patterns are shown in Figures 11 through 16. The patterns were taken with an automatic recorder. Patterns taken in the plane through the center of the slot and perpendicular to the length of the slot are designated the E-plane power patterns. Patterns taken in the plane, which includes the length of the slot and is perpendicular to the E-plane, are designated H-plane power patterns.

The patterns shown in Figure 11 and 12 were taken at a separation distance of 53.50 centimeters, which was the distance at which a minimum of the periodic variation in received power was observed. The patterns shown in Figures 13 and 14 were taken at a separation distance of 54.50 centimeters, which was

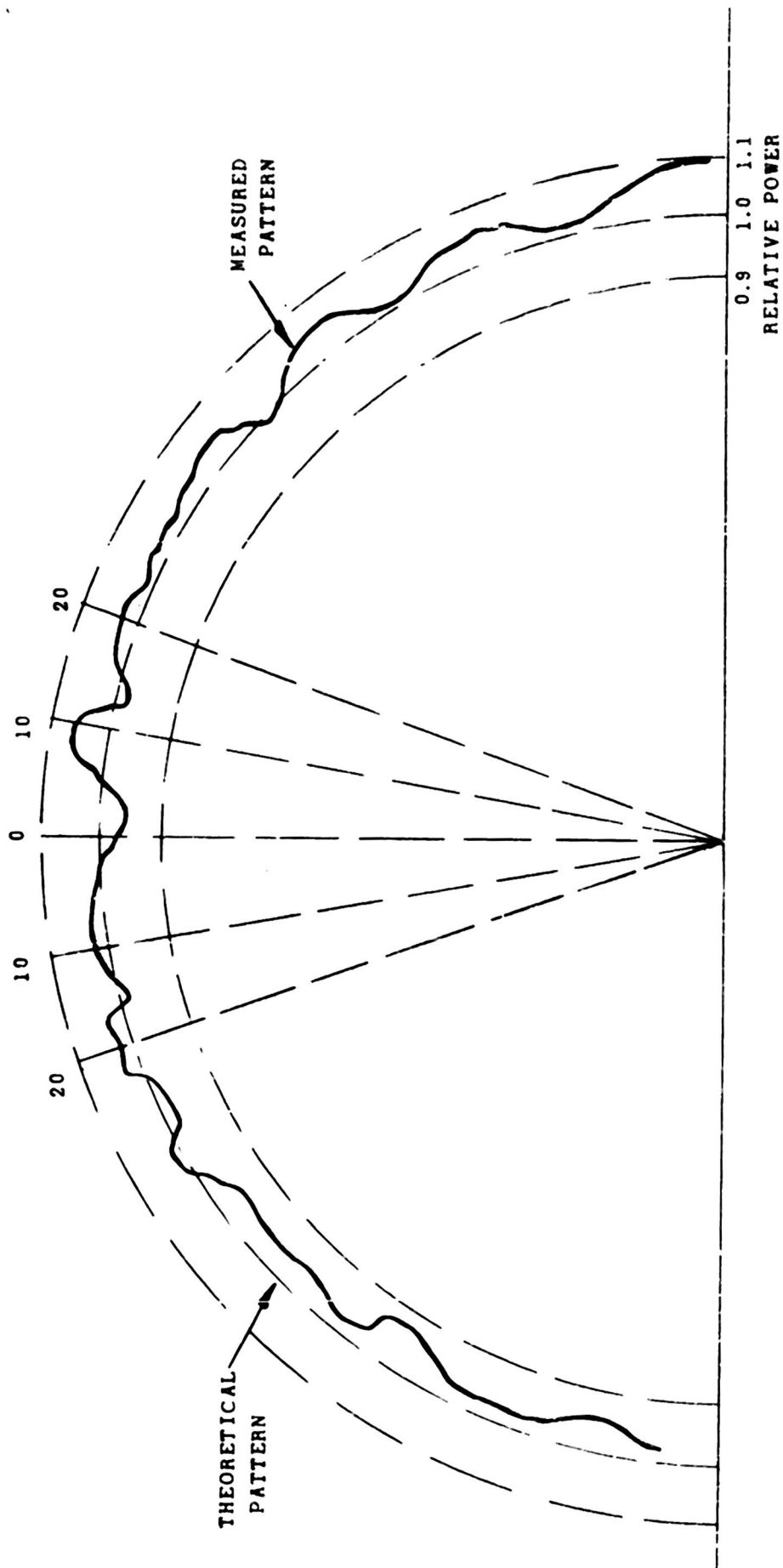


FIG. 11 THEORETICAL AND MEASURED E-PLANE POWER PATTERNS OF A THIN HALF-WAVE RESONANT SLOT IN A GROUND PLANE. MEASURED PATTERN TAKEN WITH THE HORN AT 53.50 CENTIMETERS.

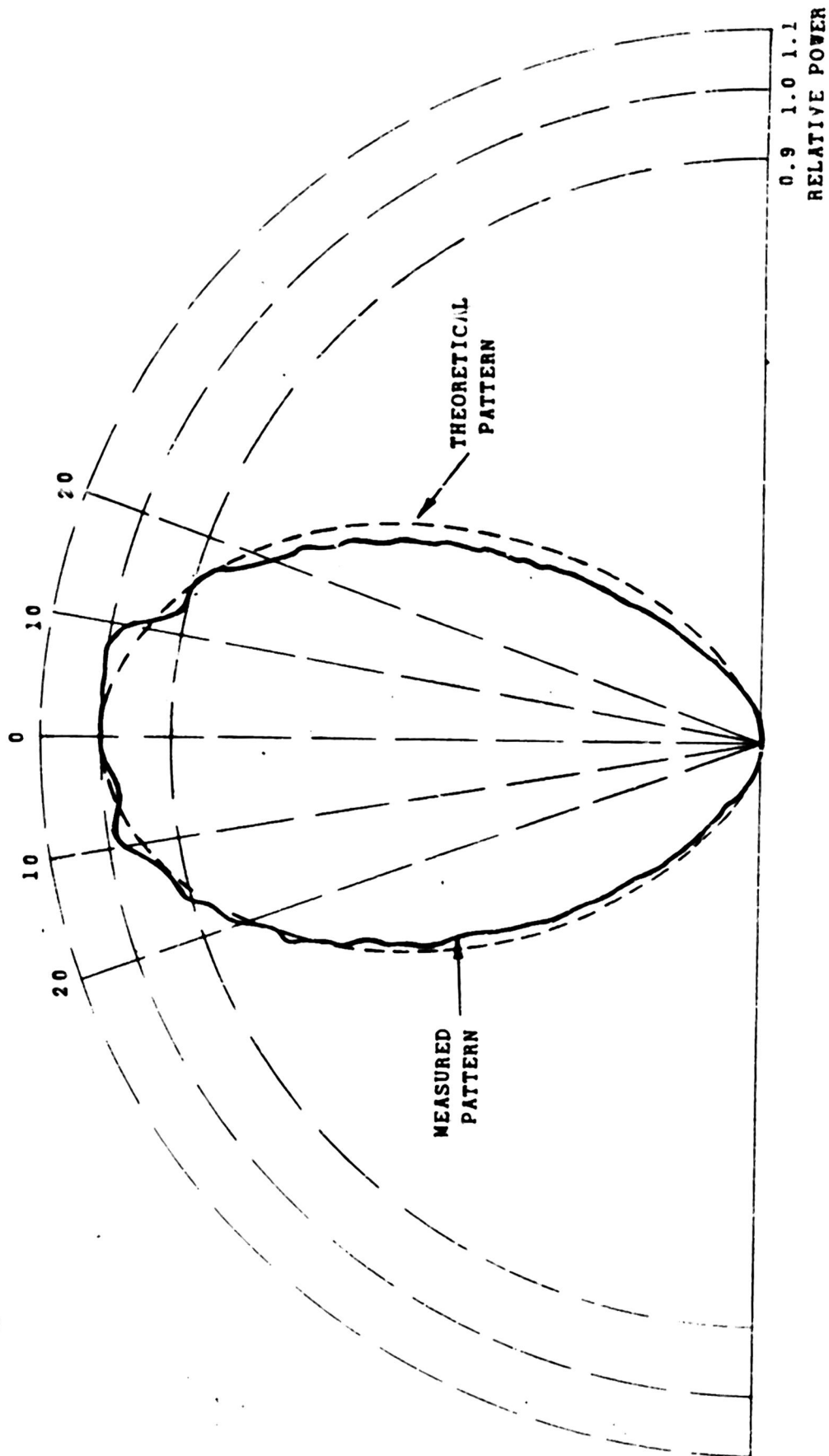


FIG. 12 THEORETICAL AND MEASURED H-PLANE POWER PATTERNS OF A THIN HALF-WAVE RESONANT SLOT IN A GROUND PLANE.. MEASURED PATTERN TAKEN WITH THE HORN AT 53.50 CENTIMETERS.

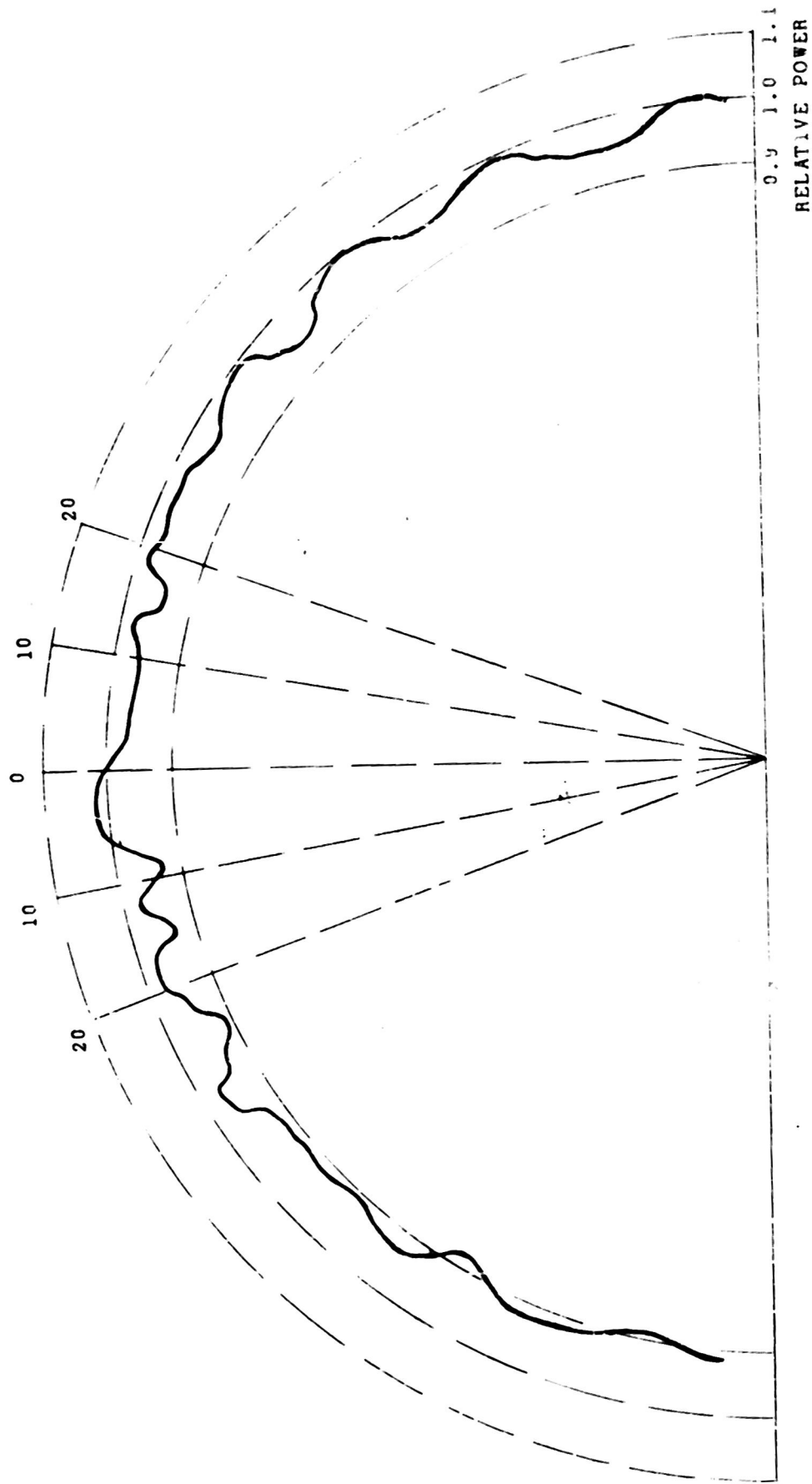


FIG. 13 E-PLANE POWER PATTERN OF A THIN HALF-WAVE RESONANT SLOT IN A GROUND PLANE. TAKEN WITH THE HORN AT 54.20 CENTIMETERS.

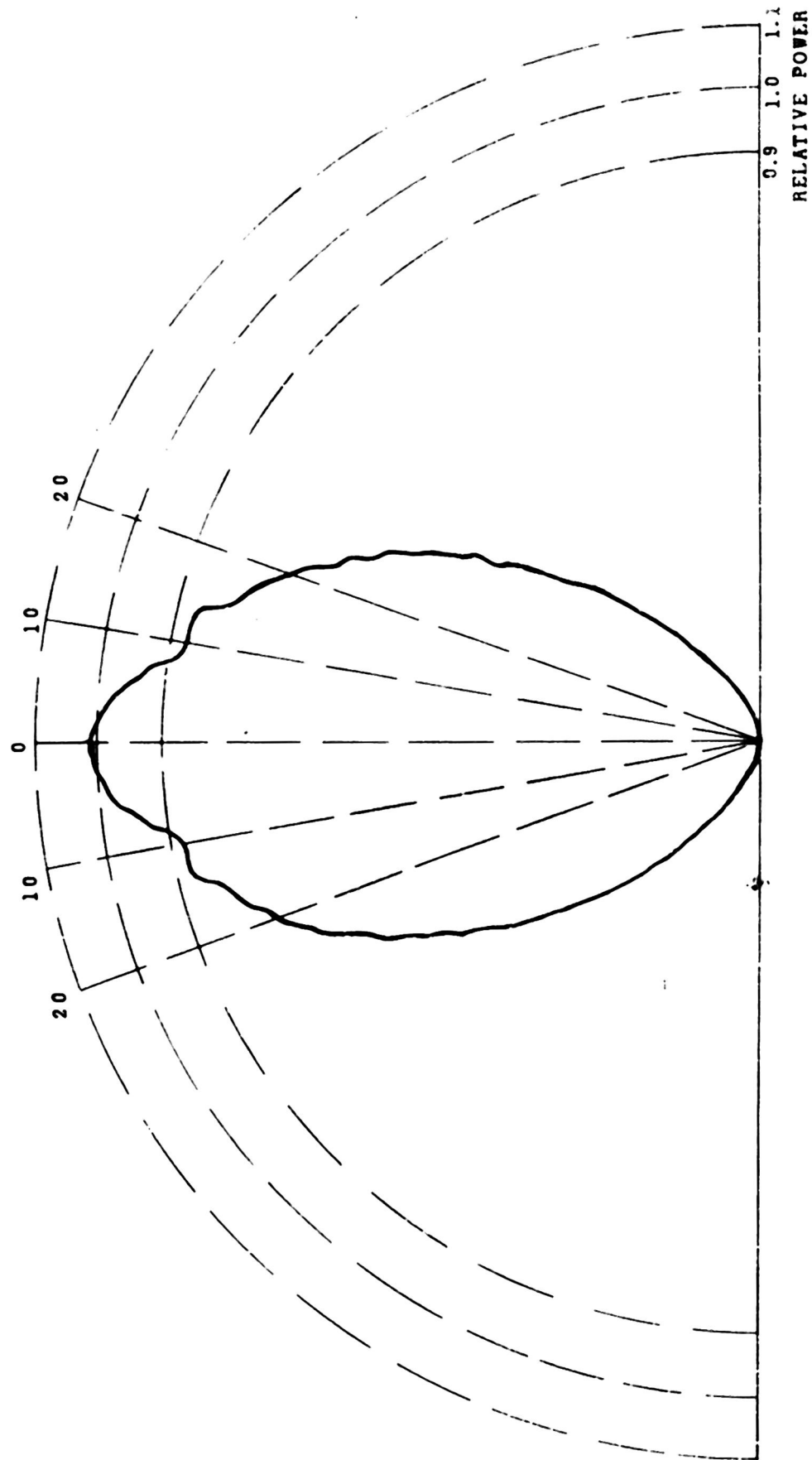


FIG 14 H-PLANE POWER PATTERN OF A THIN HALF-WAVE RESONANT SLOT
IN A GROUND PLANE TAKEN WITH THE HORN AT 54.20 CENTIMETERS.

the distance at which an adjacent maximum of the periodic variation in received power was observed. The irregularities in the patterns when the horn was almost directly over the slot show maximums and minimums which correspond to the maximums and minimums due to the periodic variation in received power. These irregularities in the patterns, then, were probably the result of multiple scattering between the horn and the ground plane.

The patterns shown in Figures 15 and 16 were taken at the greatest distances at which gain measurements were performed. From these two sets of patterns, it can be seen that a displacement of a quarter wavelength did not change the recorded patterns significantly at about 90 centimeters. This was to be expected since multiple scattering between the horn and ground plane was not important at this separation distance. The origin of the reflections which caused the irregularities in the patterns at large distances of separation is not known. The reflections could be due to the presence of the waveguide holder for the horn, the finite size of the aluminum ground plane, or the 0.020 inch discontinuity in the ground plane level between the brass slot assembly and the aluminum ground plane. It was not determined which of the possible sources of reflection was the major cause of the irregularities in the patterns at large distances of separation.

The cause of the drop in the gain curves in Figures 8, 9, and 10 may be seen from the patterns shown in Figures 15 and 16. The gain was measured at the angular position denoted by the vertical line passing through all the patterns. This angular

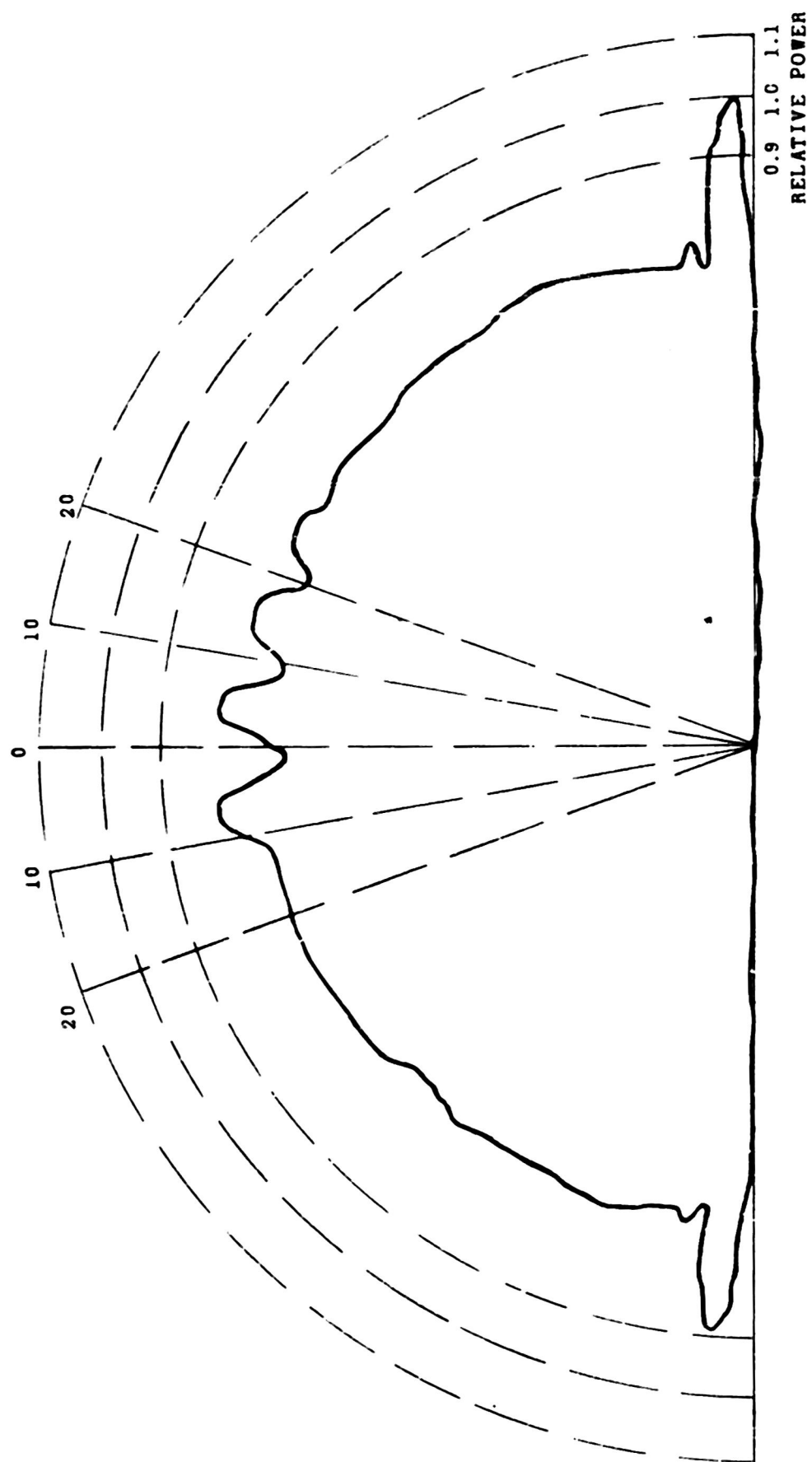


FIG. 15 E-PLANE POWER PATTERN OF A THIN HALF-WAVE RESONANT SLOT
IN A GROUND PLANE TAKEN WITH THE HORN AT 90.10 CENTIMETERS

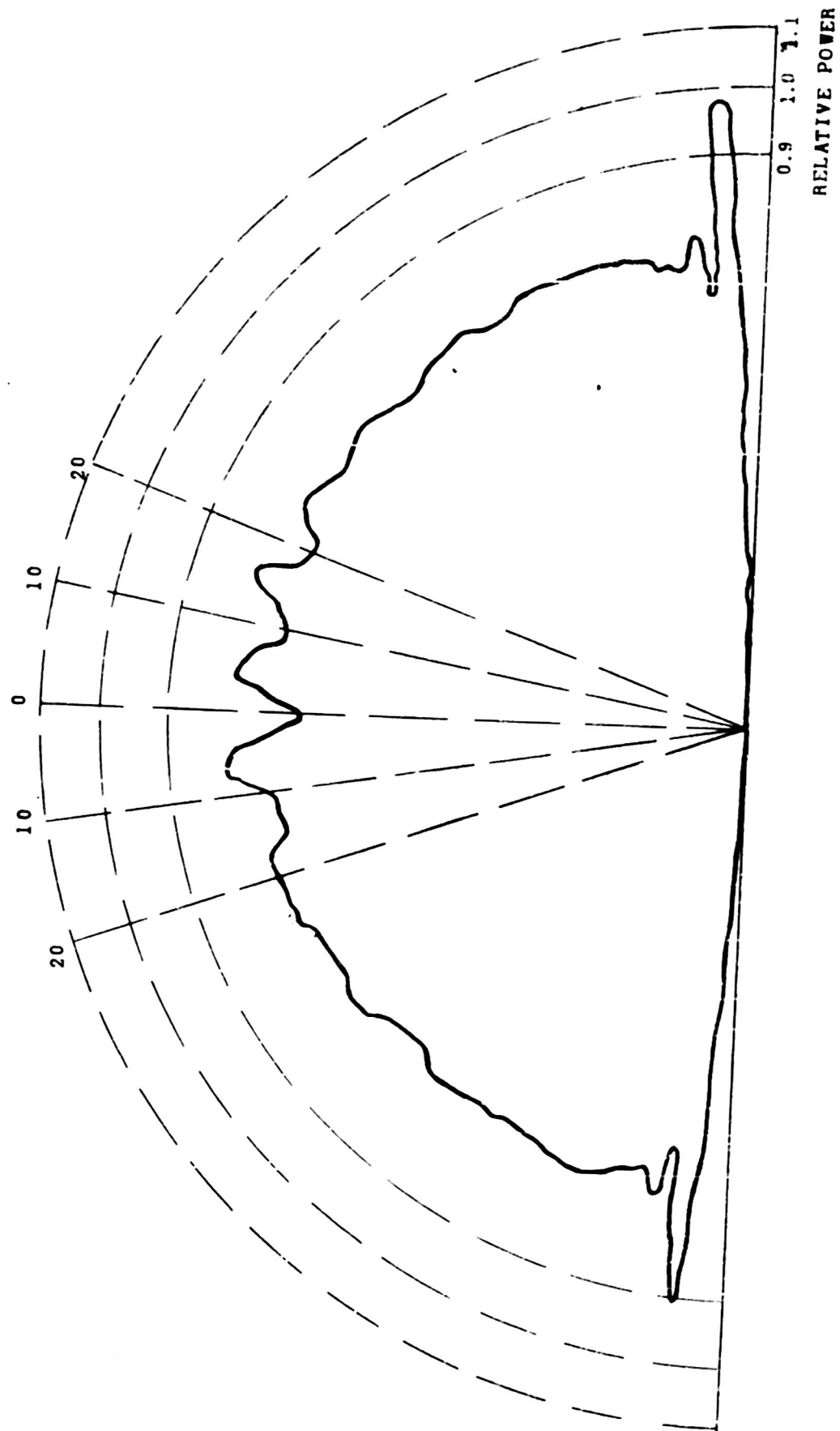


FIG. 16 E-PLANE POWER PATTERN OF A THIN HALF-WAVE RESONANT SLOT IN A GROUND PLANE. TAKEN WITH THE HORN AT 90.90 CENTIMETERS.

position passes approximately through the minimum of an irregularity in the pattern. Figure 15 showed that this irregularity was not altered significantly by a vertical movement of the horn about this distance. Therefore, the drop in the gain curves was due to some unknown reflections which caused the minimum in the irregularities of the patterns.

The experimental value of gain assigned to the thin half-wave resonant slot in the ground plane was 5.1 db. The accuracy of the experimental value of gain could only be estimated. The value of ± 0.3 db was taken as the estimated accuracy of the gain measurement.

MEASUREMENT OF THE GAIN OF A WAVEGUIDE OPENING
INTO A GROUND PLANE

The second slot antenna to be investigated was a waveguide opening into a ground plane. Since this antenna is easy to construct and since its gain may be calculated from a knowledge of the reflection coefficient in the waveguide, it was considered as a possible gain standard suitable for use in a ground plane. A gain standard, or an antenna of known gain, may be used to measure the gain of another antenna by the substitution method, or "gain comparison method", described in the introduction.

The electromagnetic fields produced by a long waveguide opening into a plane perfectly conducting sheet of infinite extent may be calculated by means of expressions given by S. Silver¹. Silver gives the fields diffracted through an aperture in an infinite plane screen in terms of the tangential electric field in the aperture.

To be applicable to the waveguide antenna under consideration here, it will be assumed that the ground plane is of infinite extent and perfectly conducting. In addition, the higher modes at the aperture will be neglected.

The construction of this slot was similar to that of the thin resonant slot. A four inch section of 1.0" x 0.5" x 0.050" waveguide was soldered perpendicularly to a circular brass plate

¹S. Silver, "On the Integral Equations of Planar Diffraction Problems", University of California Antenna Laboratory Report No. 163, December 15, 1949, pages 22-24.

1 1/4 inches in diameter and 0.020 inches thick. A square hole coinciding with the inside dimensions of the waveguide was filed out of the brass plate. A cover flange coupling was soldered to the generator end of the section of waveguide. The 1 1/4 inch brass plate was backed by a disk of 5/8 inch plywood, and mounted in the aluminum ground plane in the same way as the thin resonant slot assembly was mounted.

The electric field reflection coefficient in the waveguide was measured over a frequency range of 8.90-9.59 kilomegacycles. The necessary series of measurements was the same as that required in the impedance measurements on the thin resonant slot. The electrical distance between a reference point on the slotted section scale and the plane containing the aperture and the ground plane was measured by clamping a brass plate over the aperture. The theoretical gain of the waveguide opening into a ground plane was calculated using the values of the measured electric field reflection coefficient. The resulting values are plotted against frequency in Figure 17.

The measurement of the gain of the waveguide opening into a ground plane was performed with the same test components and ground plane structure used in the measurement of the gain of the thin half-wave resonant slot. The same large periodic variations in received power, due to multiple scattering between the horn and the ground plane, were observed as the distance between the horn and the ground plane was varied. In fact, the amplitude of the periodic variation (ratio of the maximum and minimum received powers separated by the shortest half-period) and the

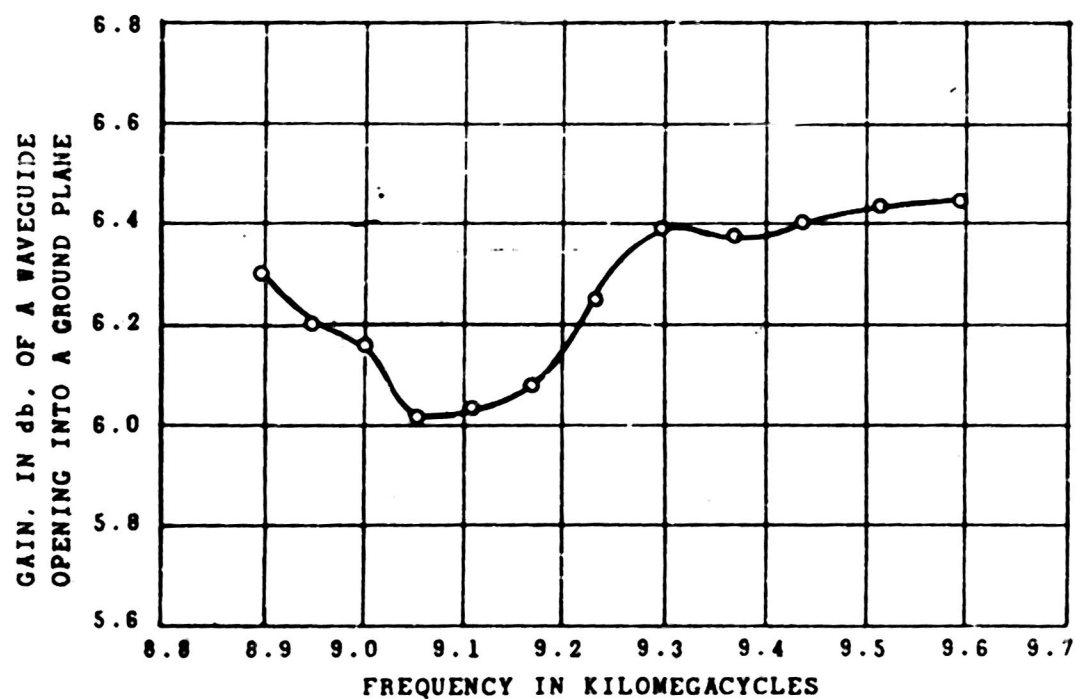


FIG. 17 GAIN OF A WAVEGUIDE OPENING INTO A GROUND PLANE AS A FUNCTION OF FREQUENCY. THE GAIN WAS CALCULATED FROM THE THEORETICAL EXPRESSION, USING THE EXPERIMENTAL VALUES OF THE REFLECTION COEFFICIENT IN THE WAVEGUIDE.

positions of the maximums and minimums of the variation were essentially the same as those observed with the thin resonant slot. Figure 7, showing one complete cycle of the periodic variation in received power, is valid for the waveguide opening into a ground plane.

The values of gain obtained for the waveguide opening into a ground plane are shown in Figures 18 and 19. The two sets of points shown in Figure 18 give the values of gain obtained for the two orientations of the slot in the ground plane. Figure 19 shows two complete sets of gain measurements taken with the same orientation of the slot in the ground plane, giving the accuracy with which each gain measurement could be reproduced. A comparison of Figure 18 with Figure 19 shows that the differences in the values of gain measured with the two slot orientations were about the same as the differences between repeated measurements of the gain at any distance. The set of gain measurements denoted by solid circles in Figure 18 is the same set denoted by solid circles in Figure 19. A comparison of Figures 18 and 19 with the corresponding gain measurements of the thin resonant slot shown in Figures 8, 9 and 10 shows that the spread in the measured values of gain of the waveguide opening into a ground plane was considerably greater than the spread in the values of gain of the thin resonant slot. The patterns of the waveguide opening into a ground plane show irregularities of correspondingly greater magnitude than those in the patterns of the thin resonant slot.

The patterns for the waveguide opening into a ground plane



ORIENTATION OF SLOT
IN GROUND PLANE

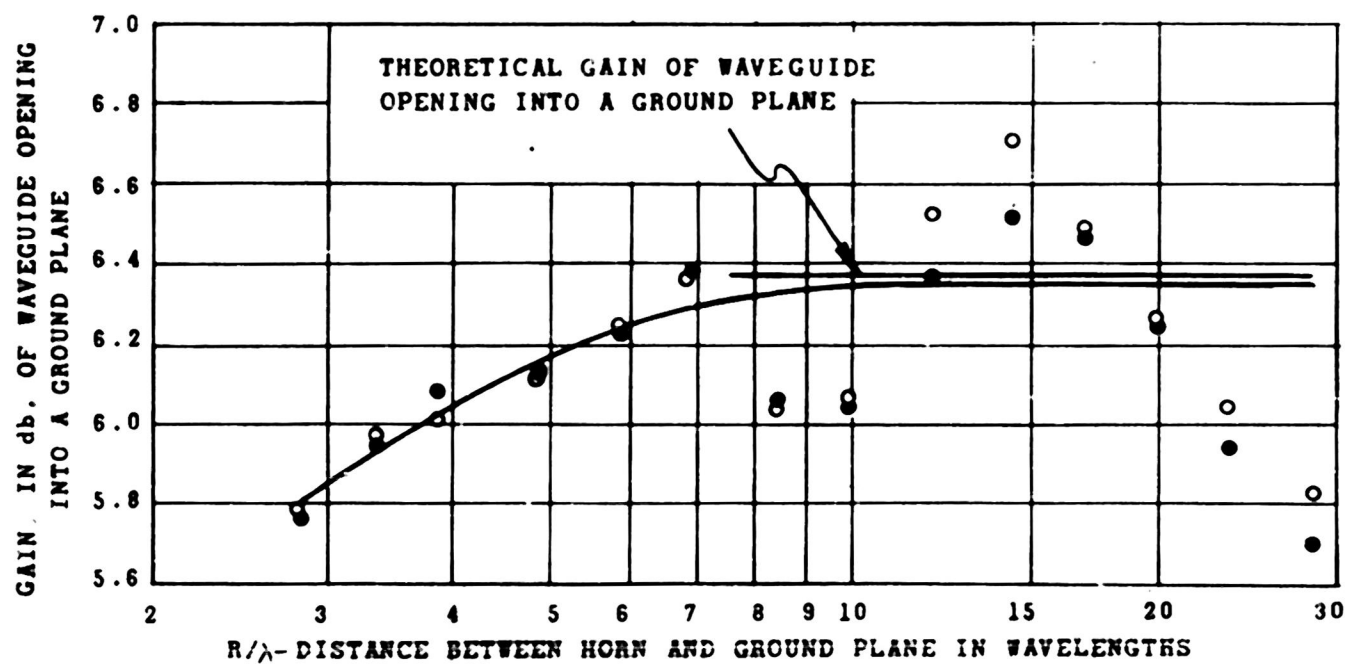
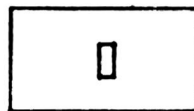


FIG. 18 TWO SETS OF GAIN MEASUREMENTS TAKEN WITH DIFFERENT
ORIENTATIONS OF THE WAVEGUIDE OPENING INTO A GROUND
PLANE.



ORIENTATION OF SLOT
IN GROUND PLANE

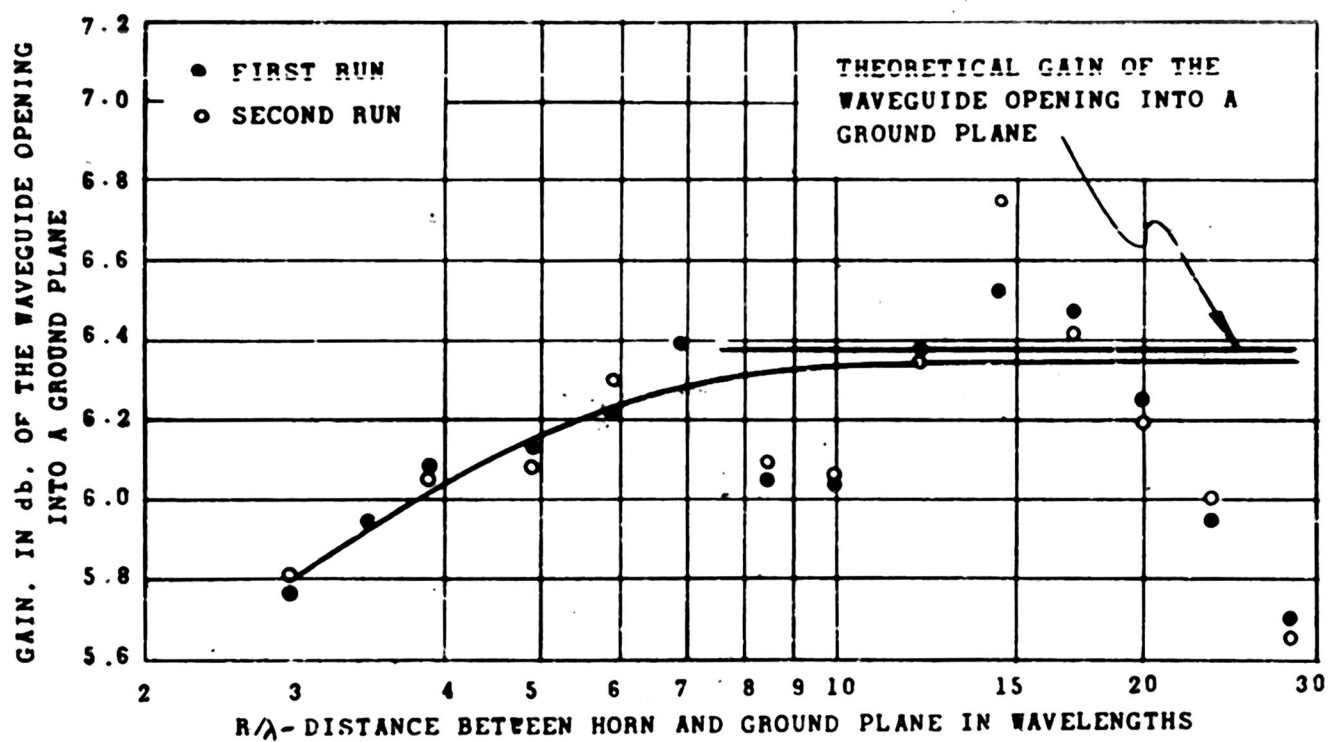


FIG. 19 TWO SETS OF GAIN MEASUREMENTS TAKEN WITH THE SAME ORIENTATION OF THE WAVEGUIDE OPENING INTO A GROUND PLANE.

are shown in Figures 20 through 23. The patterns were taken in the same way and for the same purpose as those for the thin resonant slot. From these patterns, it can be seen that a displacement of a quarter wavelength (or a half-period in the periodic variation in received power) changed the recorded patterns significantly at about 54 centimeters. However, the patterns show maximums, or peaks, when the horn was almost directly over the slot. In this respect, these patterns differed from the corresponding patterns of the thin resonant slot (Figures 11 through 14). For the waveguide opening into a ground plane, the irregularities in the patterns at 54 centimeters were probably the combined result of multiple scattering between the horn and the ground plane, and the other possible reflections which are of more importance at large distances. It is to be noted that the measured values of gain at about 54 centimeters (17 wavelengths) shown in Figures 18 and 19 were high. This result was to be expected from the presence of the peaks in the two sets of patterns in Figures 20 through 23.

The disagreement between the theoretical and measured patterns at larger angles of inclination of the horn was probably due to a rotation of the receiving assembly in the beam.

A displacement of a quarter wavelength did not change the recorded patterns significantly at about 90 centimeters. This was to be expected since multiple scattering between the horn and the ground plane was not important at this separation distance.

The value of gain assigned to the waveguide opening into a ground plane was 6.4 db. The accuracy of this value of gain was

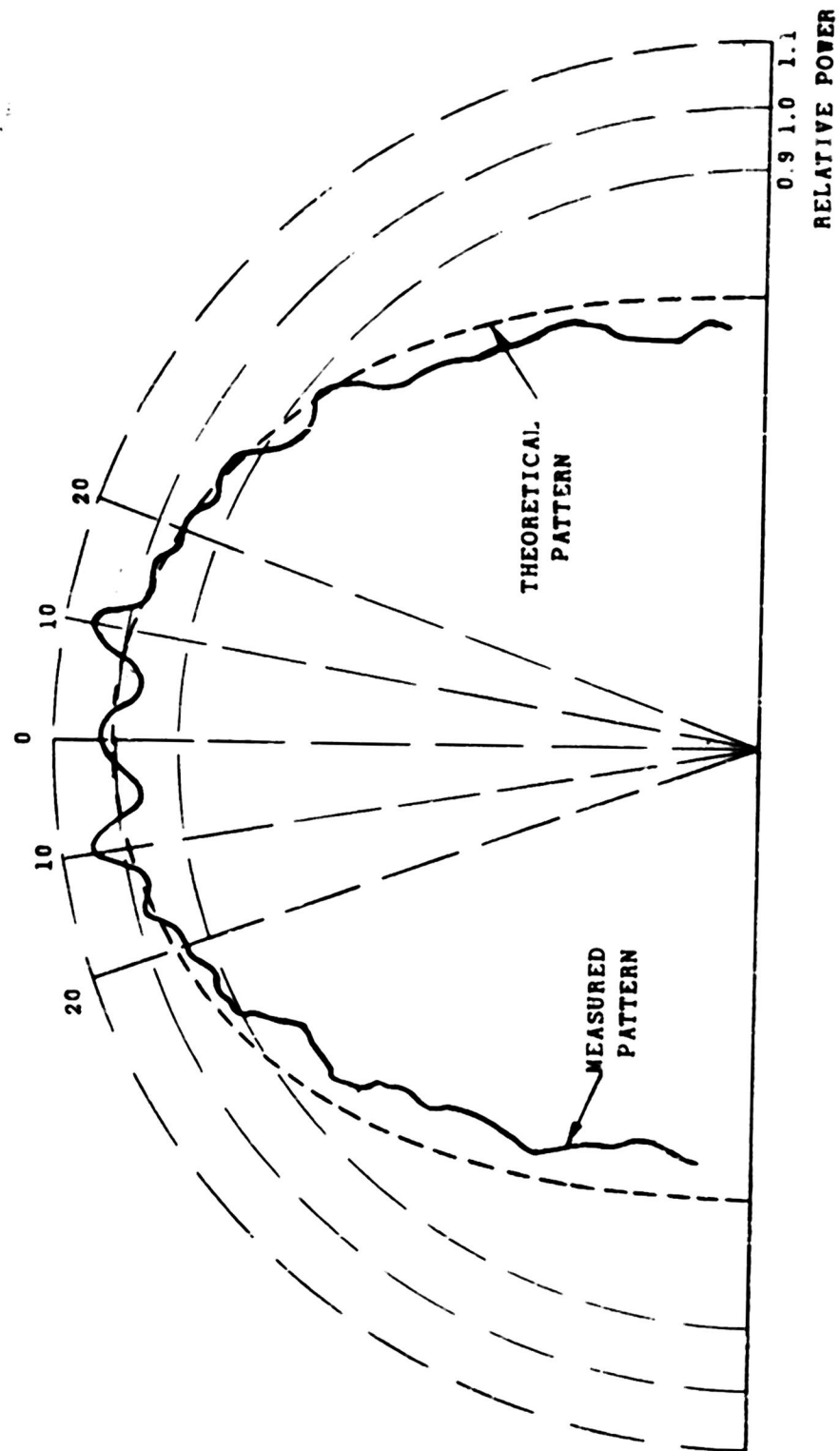


FIG. 20 THEORETICAL AND MEASURED E-PLANE POWER PATTERNS OF A WAVEGUIDE OPENING INTO A GROUND PLANE. MEASURED PATTERN TAKEN WITH THE HORN AT 53.50 CENTIMETERS.

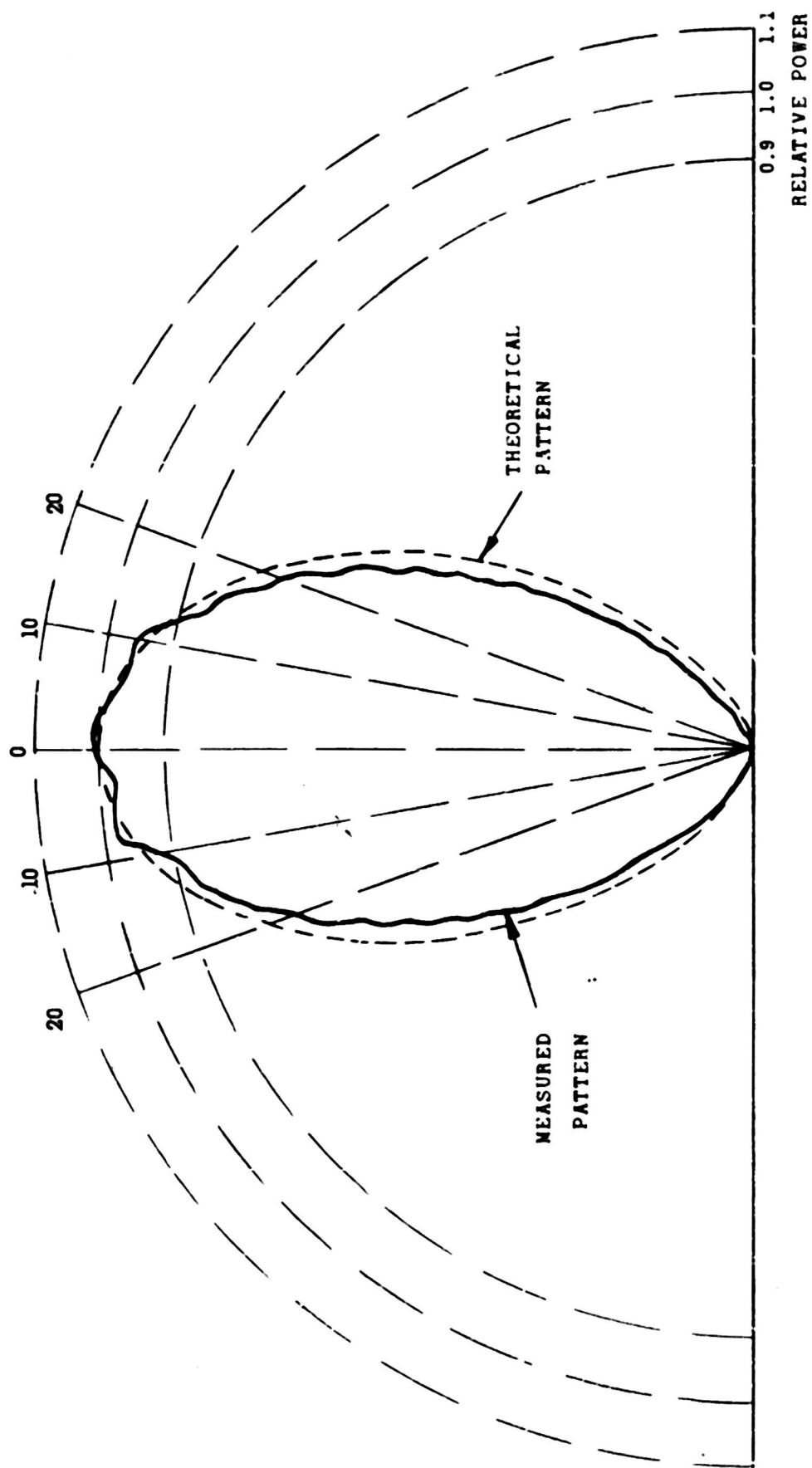


FIG. 21 THEORETICAL AND MEASURED H-PLANE POWER PATTERNS OF A WAVEGUIDE OPENING INTO A GROUND PLANE. MEASURED PATTERN TAKEN WITH THE HORN AT 53.50 CENTIMETERS.

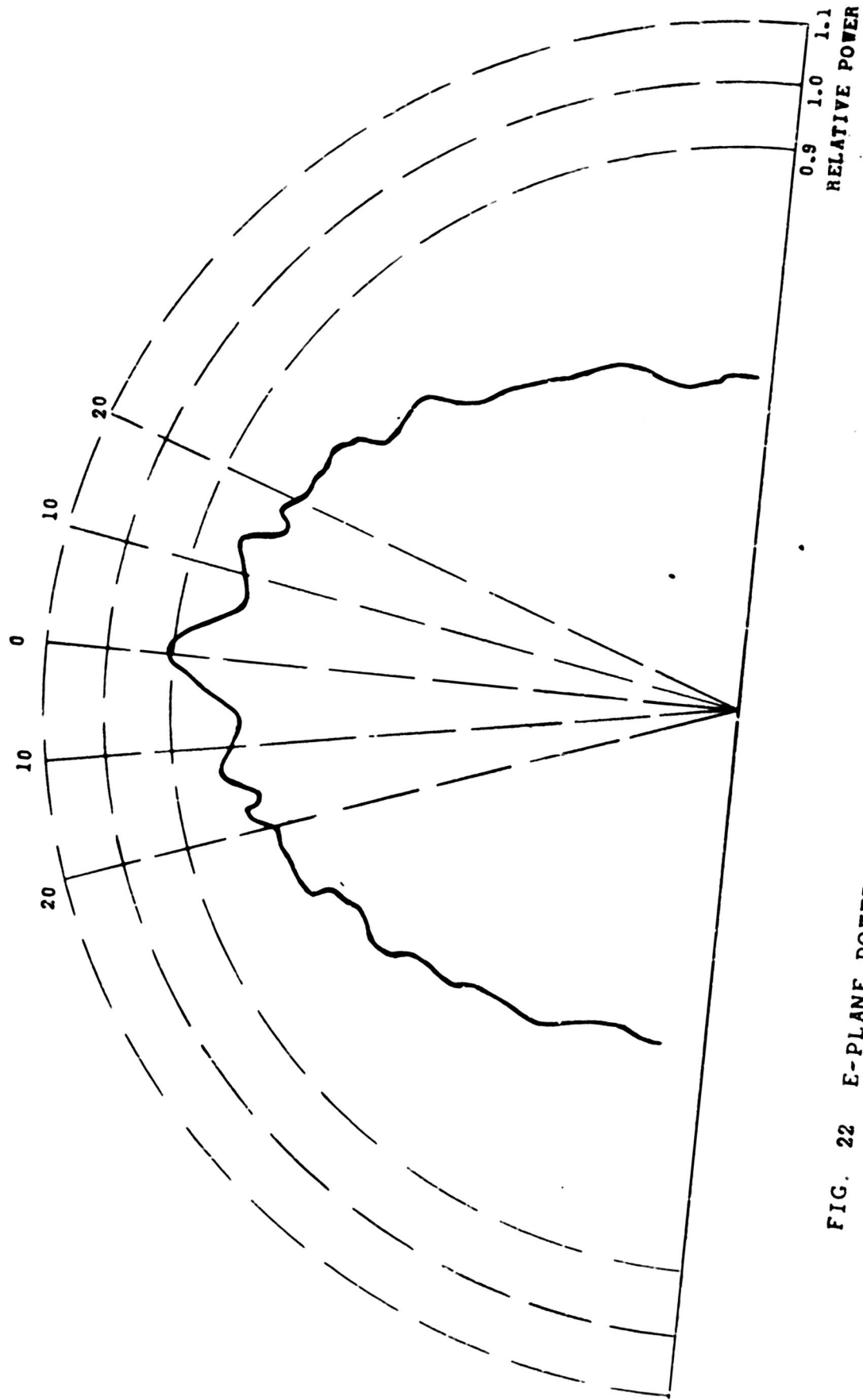


FIG. 22 E-PLANE POWER PATTERN OF A WAVEGUIDE OPENING INTO A GROUND PLANE. TAKEN WITH THE HORN AT 54.20 CENTIMETERS.

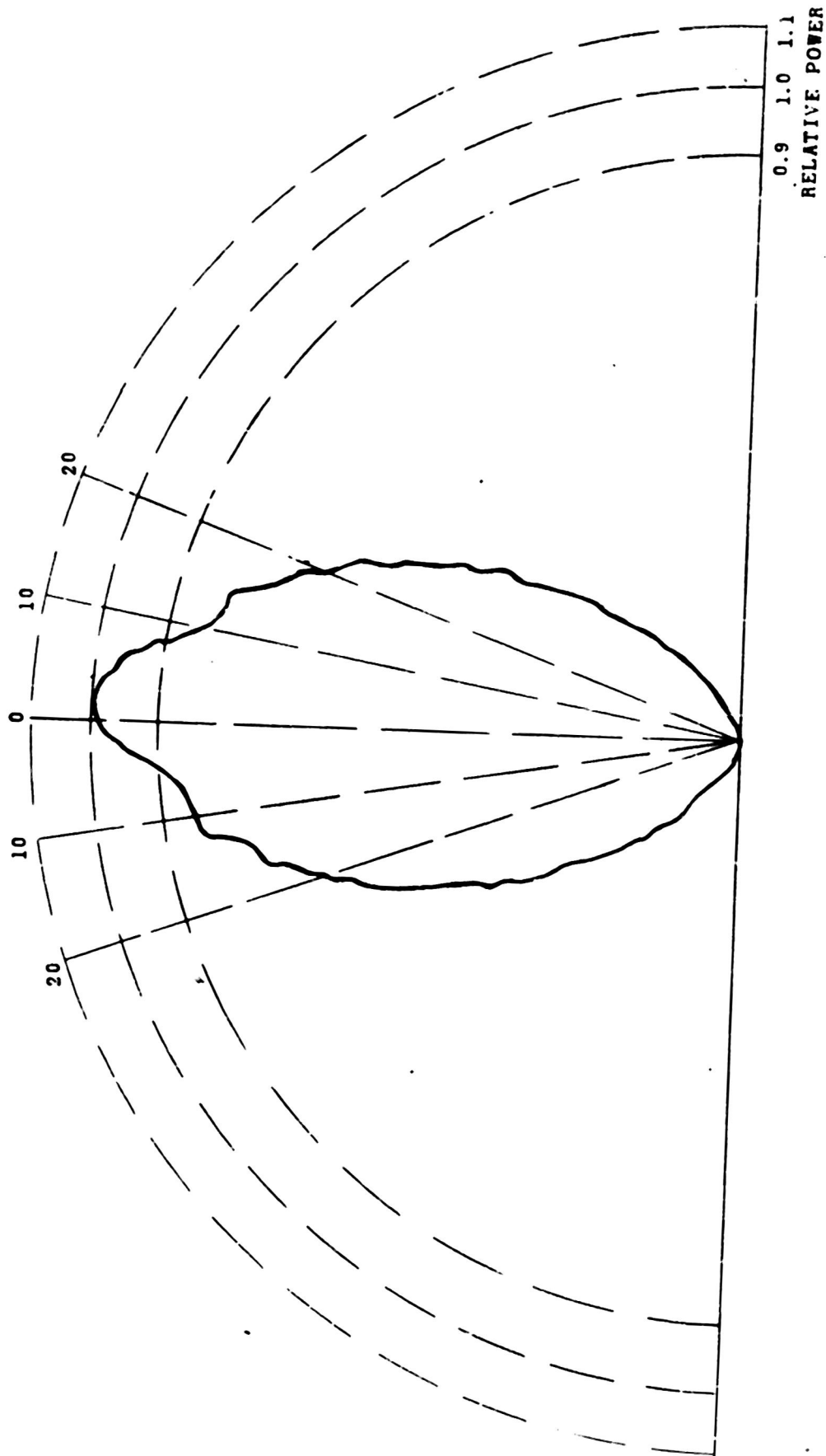


FIG 23 H-PLANE POWER PATTERN OF A WAVEGUIDE OPENING INTO A
GROUND PLANE TAKEN WITH THE HORN AT 54.20 CENTIMETERS.

less than that for the thin resonant slot. An estimate of the error can be made by adding to the estimated error of the gain of the thin resonant slot an error of ± 0.2 db, which could represent the uncertainty in the value of gain finally reached at some distance beyond 7 wavelengths. In this case, the estimated error in the value of gain assigned to the waveguide opening into a ground plane would be ± 0.5 db, or about ± 12 percent. Therefore, the measured value of gain of this antenna is 6.4 db ± 0.5 db. The theoretical value of gain is 6.37 db.

CONCLUSION

The estimated error in the experimental value of gain assigned to the thin half-wave resonant slot in a ground plane was ± 0.3 db, and the assigned value of gain differed by less than 0.1 db from the theoretical value of gain. The estimated error in the gain assigned to the waveguide opening into a ground plane was ± 0.5 db, and the assigned value of gain differed by less than 0.1 db from the theoretical value of gain. For the two slot antennas, then, it can be said that the theoretical and experimental values of gain agreed to within the estimated errors in the gain measurements.

The presence of reflections was the major difficulty encountered in the measurements of the gains of the slot antennas. At short distances of separation, multiple scattering caused large periodic variations in received power; and at greater distances of separation, reflections from the ground plane beam, the receiving assembly, and the edges of the ground plane caused large variations in received power. The use of absorbing cloth on the metallic parts behind the receiving horn considerably reduced the amplitude of the periodic variation in received power due to multiple scattering.

From the results of the gain measurements described in the preceding pages, it appears necessary to employ the averaging procedure to eliminate the effects of multiple scattering. Because of the reflections present at large distances, the gain measurements had to be performed at relatively short distances

of separation where the amplitude of the periodic variation in received power was large. In particular, the most reliable values of gain were measured at the relatively short distances where the gain was just reaching its final value.

The waveguide opening into a ground plane was not considered to be a satisfactory gain standard. For use as a gain standard in the "gain comparison method", where the accuracy of the gain measurement is directly dependent on the accuracy of the gain standard, an estimated error of ± 0.5 db in the standard would be excessive for a precision gain measurement. However, if this accuracy is sufficient, the waveguide opening into a ground plane could be used to measure the gains of other slots in ground planes by the "gain comparison method". Greater accuracy could be achieved using the thin resonant slot as the gain standard. However, the gain of the thin resonant slot varies rapidly with the operating frequency. Gain measurements with this slot would have to be performed at the resonant frequency of the slot.